PLANETARY SCIENCE
TECHNOLOGY REVIEW PANEL

Lunar Surface Science
Risk Reduction & Advanced Development

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Lunar Quest Program Overview

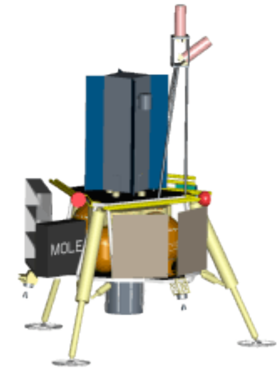
- The Lunar Quest Program (LQP) is a loosely coupled, strategic program with the goal of: providing lunar science Missions and Research to address community-prioritized science objectives

- Pending the results of the next Decadal Survey, the LQP derives it's science requirements for Missions and Research primarily from *The Scientific Context for Exploration of the Moon* (SCEM) report (National Academies NRC, 2007)

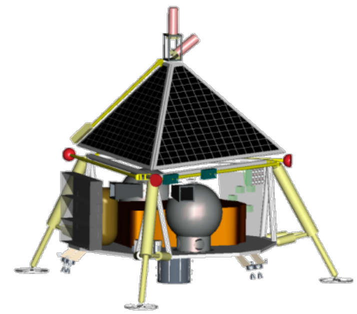
– LQP Program elements include:
  - Flight Missions: Lunar Reconnaissance Orbiter Science (LRO), Lunar Atmosphere and Dust Environment Explorer (LADEE), & Lunar Surface Science Advanced Development Activities
  - Missions of Opportunity (TBD)
  - Research & Analysis: NASA Lunar Science Institute (NLSI), Lunar Advanced Science & Exploration Research (LASER), and other lunar-focused awards

Lunar Surface Science Evolution

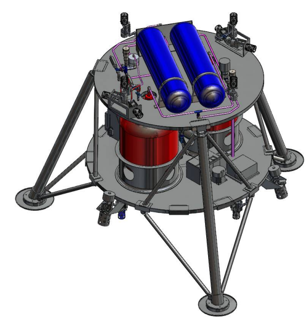
- The LQP was initially directed to formulate the International Lunar Network (ILN) Anchor Nodes Mission, the U.S. contribution to the ILN
  - The ILN is an initiative of nine national space agencies to establish a set of geophysical monitoring stations on the surface of the Moon
- The ILN Science Definition Team (SDT) defined ILN science objectives. Two mission concepts were developed by MSFC/APL based on SMD direction
- Due to the cost of all ILN 2 or 4 Node Mission concepts, lunar network science has been referred to the Decadal Survey for prioritization
  - Pending results of the Decadal Survey, the Robotic Lunar Lander Development Team (RLLDT) is utilizing an extended formulation phase to perform engineering tests and risk reduction activities to support the development of a small lunar lander for future lunar surface science, including:
  - Lander sub-system testing (i.e. propulsion, power, thermal, etc)
  - Development of Hardware-in-the-Loop testbed to develop and test landing algorithms and thruster placement



ASRG lander



Solar/Battery lander



Warm gas testbed lander

Decision Making Processes Used

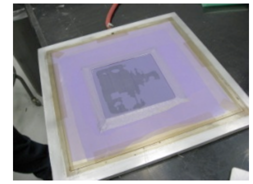
- Objective: Utilize extended formulation period to perform value-added work in an effort to reduce risk in the development and implementation phases of a future lunar lander project.

- Risk Reduction Activity Prioritization
  - Started with a flight design (ILN Anchor Node) and performed risk assessment
  - Focused on unique required capabilities and identified technical challenges
  - Polled subsystems for candidate activities / methods to address their main risk areas
  - Consolidated proposed activities and reviewed with systems engineering team
  - Reviewed with Project Management and assigned priorities to each activity
  - Initiated all “High” priority activities

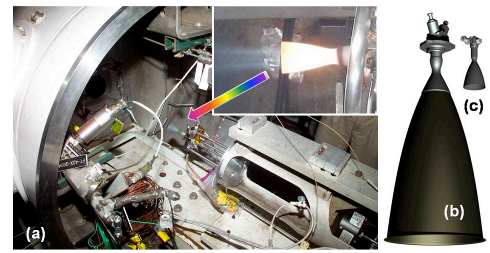
- Integrated schedule includes all high priority risk reduction activities

Lunar Surface Science Risk Reduction

- **Risk Reduction Activities Currently On-Going**
  - Lunar Lander Test Bed: Hardware in the Loop (HWIL) testing with landing algorithms and thruster positions
  - Propulsion: thruster testing in relevant environment, pressure regulator valve
  - Power: battery life testing
  - Thermal: Warm Electronics Box and Radiator analysis
  - Structures/Mechanical: composite coupon testing, lander leg stability testing, adapter/separation system
  - Avionics: reduced mass and power avionics box with LEON3 processor (prototype, software, testbed)
  - GN&C: landing algorithms, ground data system
  - RF Comm: antenna risk reduction
  - Mole testing @ JPL: test mole in lunar regolith simulant
  - Seismograph task: analysis to inform the requirement for the number and location of sites

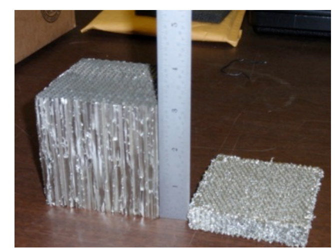


Composite test panel



100 lbf thruster testing

Li-CoAlO$_2$ Alloy Battery



3" Core honeycomb structure material
Before and after crush test

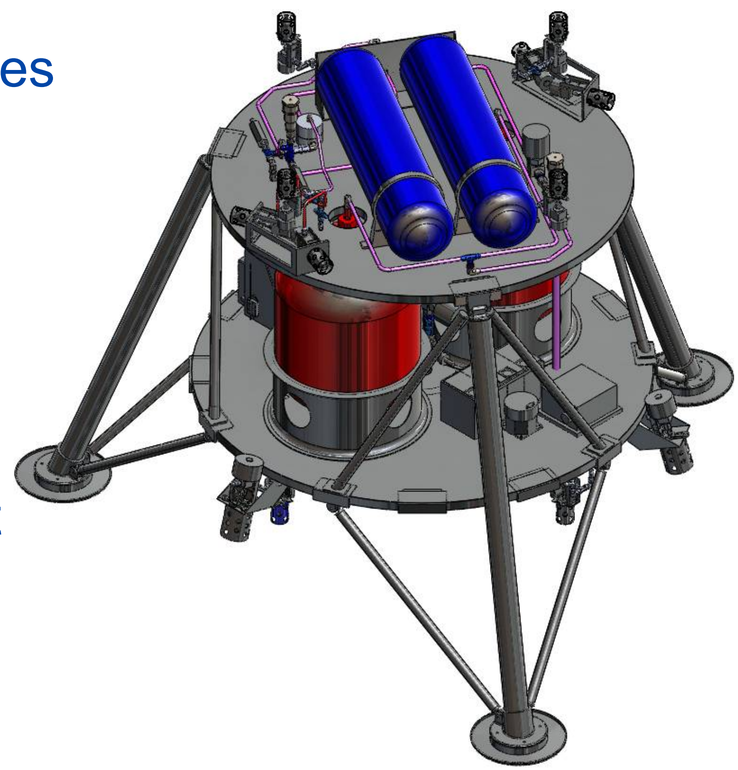
Robotic Lander Testbed: Incremental Development Approach for Flight Robotic Lander Design

- **Cold Gas Test Article (Operational)**
  - Completed in 9 months
  - Emulates Robotic Flight Lander design for thruster configuration in 1/6th gravity
  - Flight time of 10 seconds at 3,000 psi
  - Demonstrates autonomous controlled descent and attitude control
  - Utilizes compressed air for safety, operational simplicity, and multiple tests per day
- **Warm Gas Test Article (Summer 2010) :**
  - Longer flight duration (approx. 1 min) and greater altitude for more complex testing
  - Utilizes Robotic Flight Lander design sensor suite, software environment, avionics components (processors), GN&C algorithms and ground control software
  - Serves as a pathfinder for flight lander design and development
  - Quick turn around time to allow multiple tests per day
  - Open to academia and private industry for technology testing

Test bed provides for **autonomous closed loop** control to demonstrate landing capability on airless bodies to build confidence and reduce overall risk.

Robotic Lander Testbed: Warm Gas Test Article

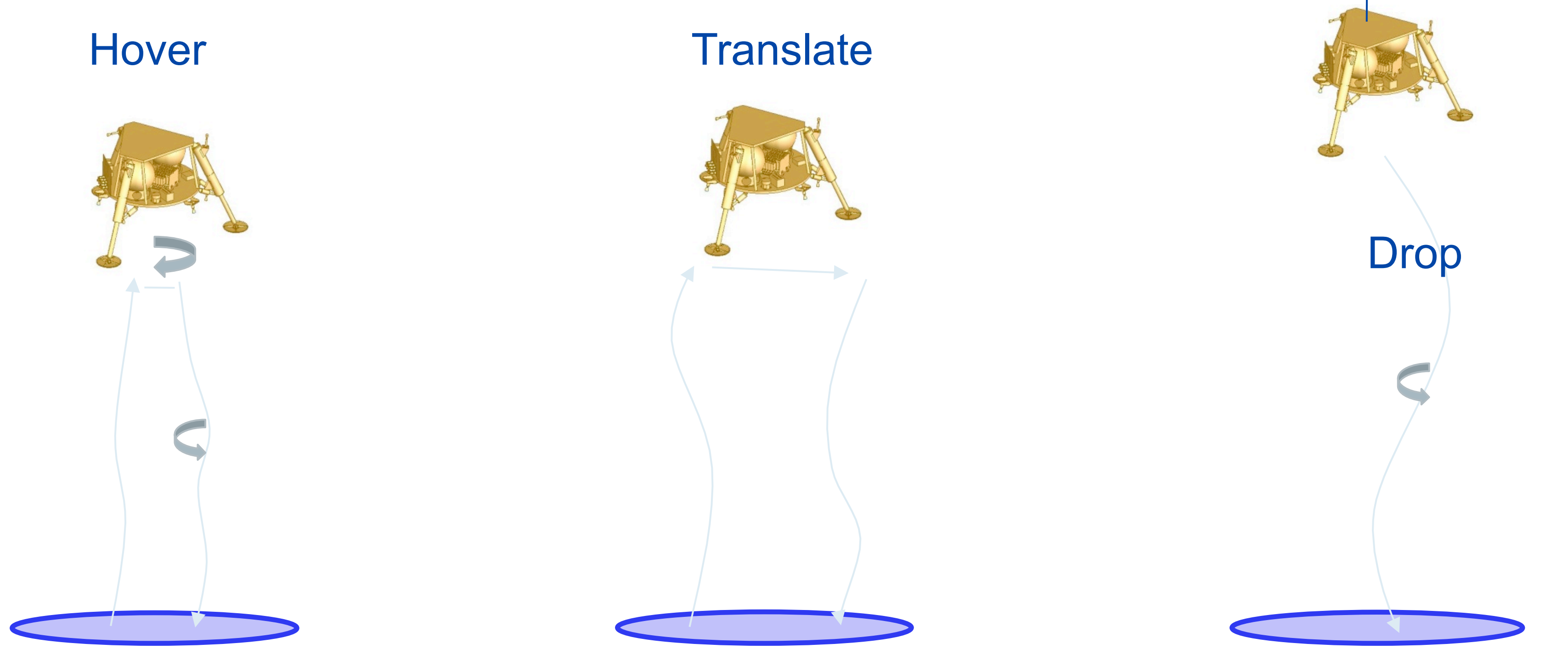
- Demonstrate the terminal descent phase capability for a robotic airless body lander
  - Goal 1: The test article will Use flight system engineering, design, and processes when / where appropriate to gain experience.
  - Goal 2: The test article will Perform Operational Flight Tests by August 2010
  - Goal 3: The test article will be similar to ILN (International Lunar Network) in flight dynamics and appearance.
  - Goal 4: The test article will achieve flight times close to one minute in duration and 30 meters altitude.



Lunar Surface Science Risk Reduction

Warm Gas Testbed Testing Scenarios

- Assuming Integration Begins – April 2010
- Begin Preliminary Testing – June 2010
- Demonstrate Flight Tests – August 2010



What Worked Well and Why

- By starting with a flight mission concept design and then identifying risks and focusing effort on the highest risks, the engineering team has been very engaged and is realizing significant value from the effort.
- This approach led to flight-like testbeds and risk reduction activity that is directly applicable to the future mission—very different from a typical “technology push” development program.
- Significant intangible benefits in developing teaming relationships between MSFC and APL, and gaining experience in implementation processes such as combined systems engineering approach, combined safety and mission assurance approach, fabrication standards, testing, procurements, contracting, etc.